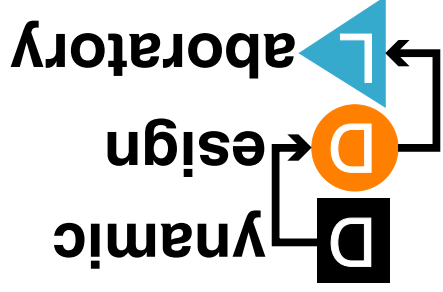


GPS as a Tire Condition Monitor

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Outline

- Motivate Tires
- Applications for the invention
- The Invention
- Positive Impact
- Contrast to Other Ideas
- What is Currently in the Works

Why Care About Tires?

■ Everyone should, at least a little bit

- Tires connect the car to the road

■ Safety

- Premature failure

- Vehicle stability, dynamics

- The largest source of uncertainty for ESP systems

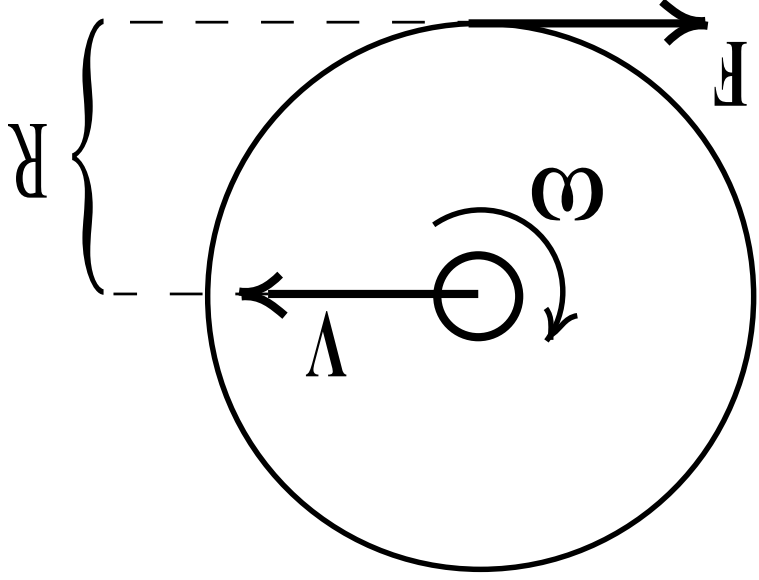
■ Efficiency

- Inflation pressure directly effects fuel consumption
- Inflation pressure directly effects tire wear

Applications for Tire Condition Monitor

- Tire Wear Indicator
 - According to DOT one of the leading causes of on-road tire failure is severely worn tires
- Stability control programs
 - Vehicles with ESP have 30-35% reduction of single vehicle crashes according to 5 independent studies (ESC coalition)
 - Knowing tire properties makes ESP work better
- Tire pressure sensing
 - These slides focus on tire pressure benefits

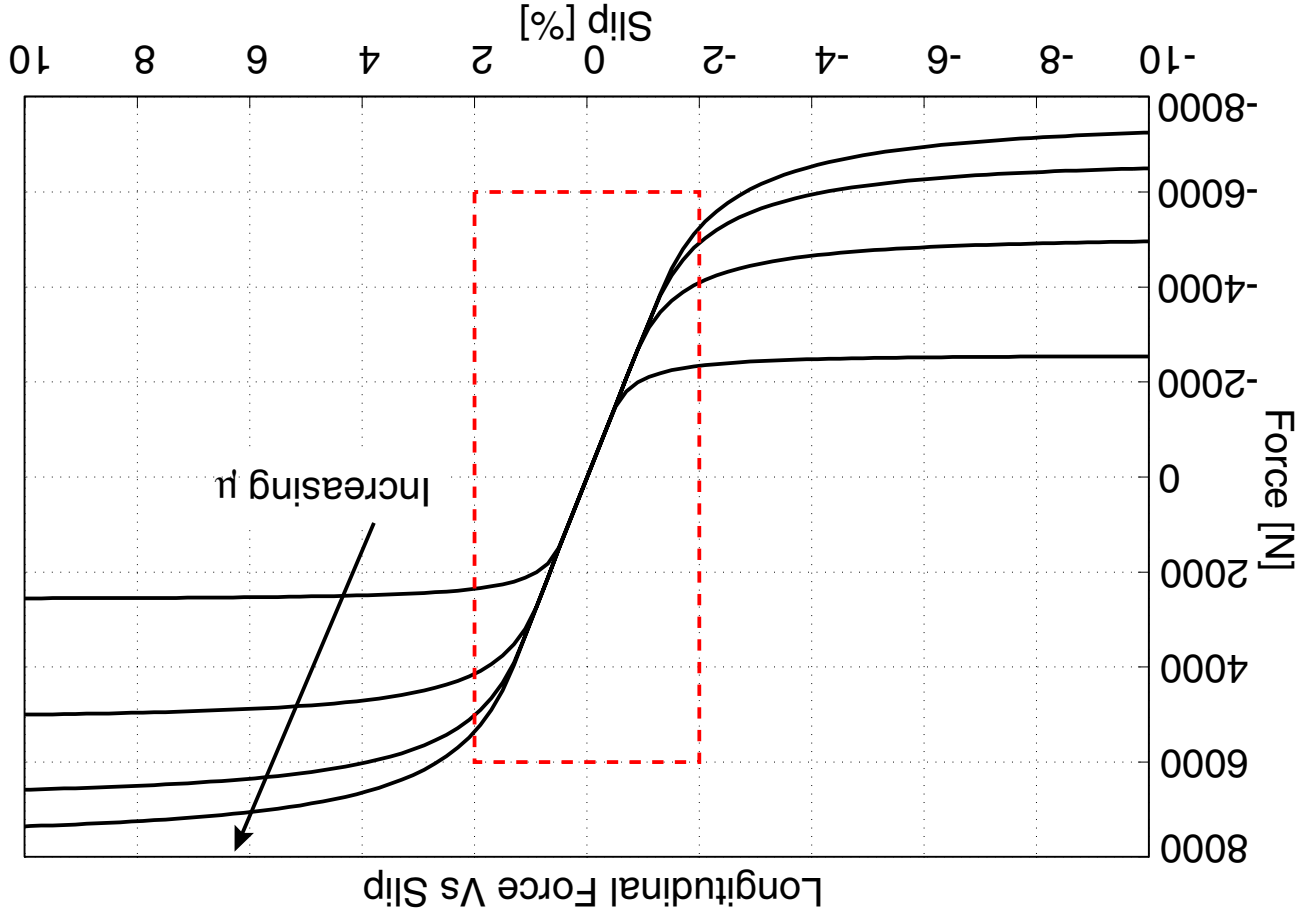
Longitudinal Tire Properties



$$V \neq R\omega$$

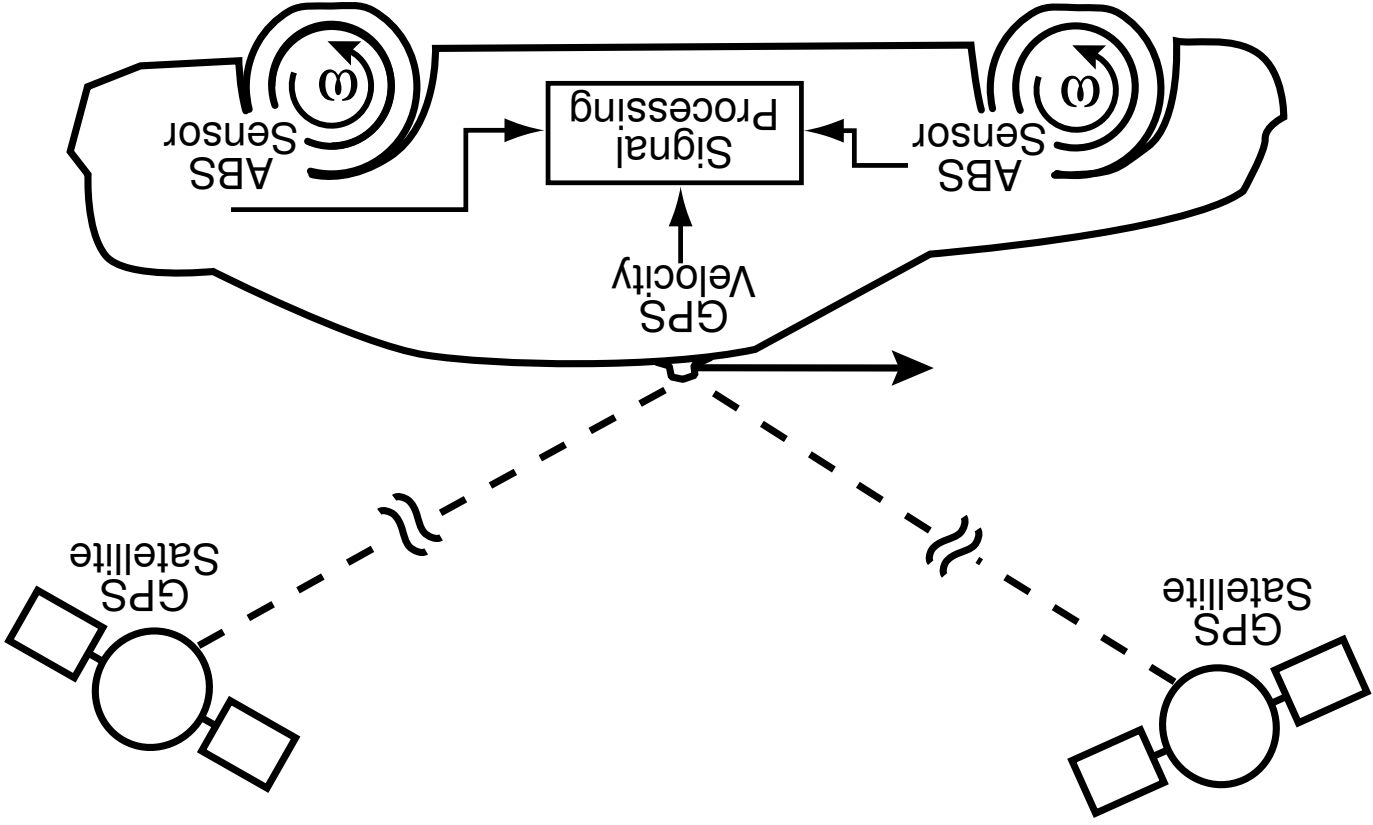
$$\text{Slip} = - \left(\frac{V - R\omega}{V} \right)$$

Force Vs Slip Curves



$$F = C_x \left(\frac{V - R\omega}{V} \right), \text{ for low values of slip}$$

Invention Schematic

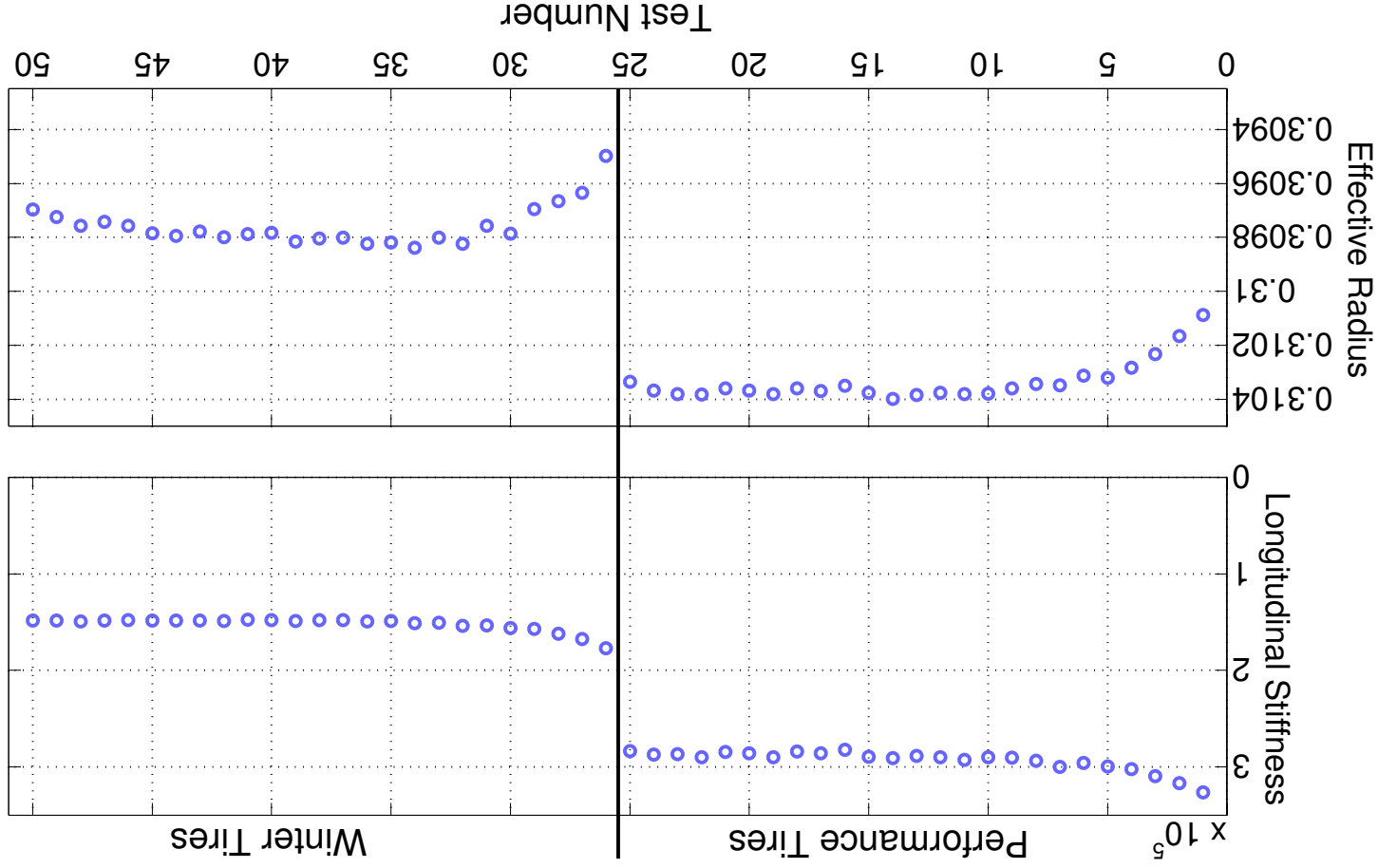


■ GPS is extremely accurate (2 cm/s CEP)

Test Vehicle



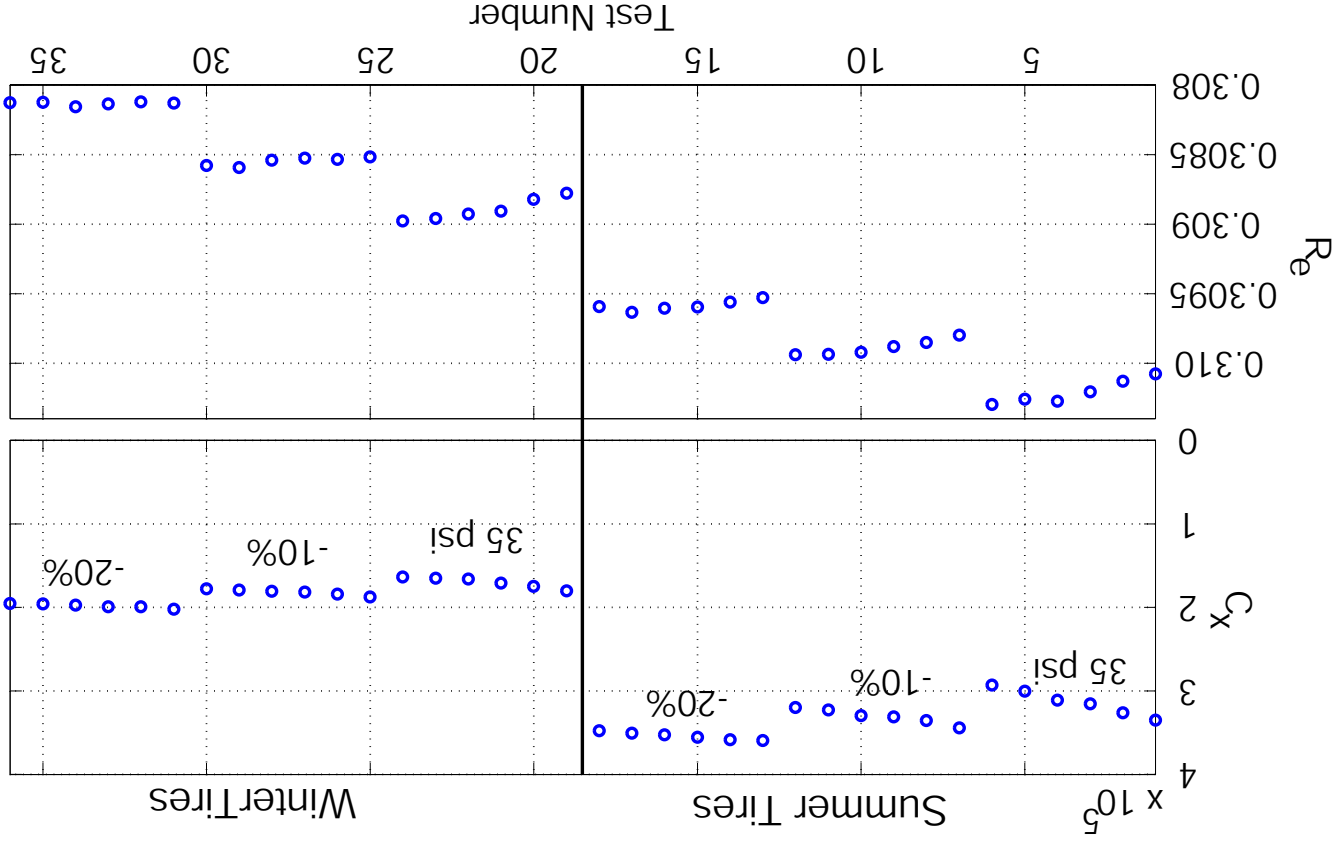
Invention Performance



Estimates are extremely accurate as tires warm up

Invention Performance

Tire property estimates for different tire pressures



■ A 10% decrease in tire pressure yields a 10% increase in stiffness

Tire Pressure Sensing via Longitudinal Stiffness

■ Indirect sensing method

- Many sensors are indirect
- Mass airflow from a hot wire being cooled
- Thermometer from a calibrated volume change

■ Account for tire wear and warm up, then infer pressure from stiffness

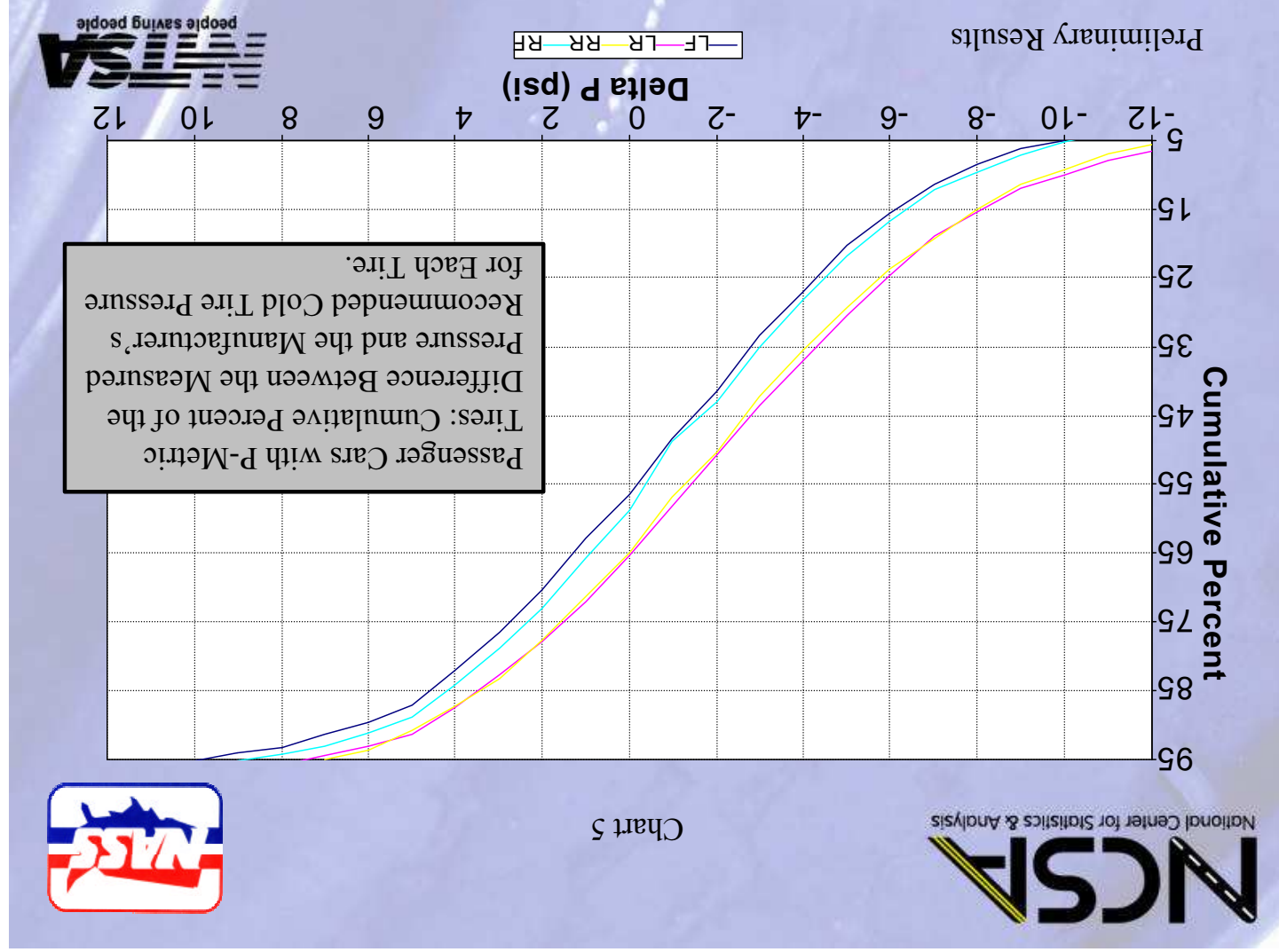
- Model tire wear as a function of driving distance
- Model tire warm up as a function of slip and time

The Need: Tire Pressure Sensing

A large number of cars have underinflated tires

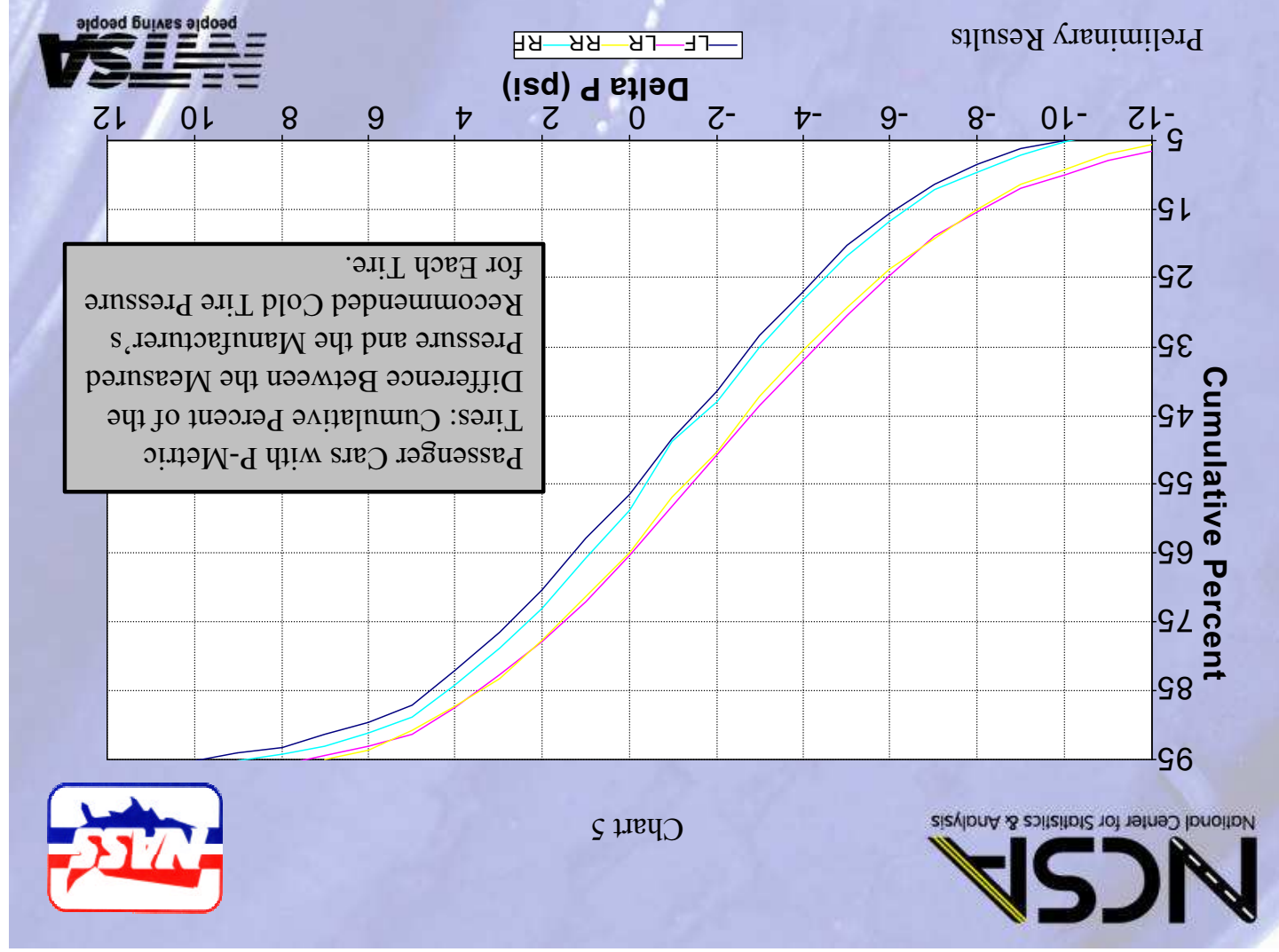
According to survey, people check their tire pressure rarely, irregularly

36% have at least one tire 20% below



The Need: Tire Pressure Sensing

Survey results probably conservative: some tires were measured warm.



Economic Impact

- Goodyear research showed
 - 6% underinflation average \Rightarrow 0.6% more fuel consumed
 - 6% underinflation average \Rightarrow 3.2% more tread wear
- 16M cars, 17 mpg, \$1.44/gal, (NHTSA, DOT, DOE)
 - \$100M in first year, \$800M over life of vehicles in fuel savings
 - \$300M the second year and \$1.5B in 5 years
- Tire life also improves, \$61/tire, 45k m/tire (NHTSA)
 - \$33M the first year and \$275M over the life of the fleet
 - \$66M the second year and \$495M in 5 years

Environmental Impact

- The US automotive fleet produces 300M tons of greenhouse gasses per year (DOE)
 - In one year, preventing 6% underinflation saves 120k tons
 - In five years, it saves 1.83M tons
 - A properly maintained fleet will save the US 1.8M tons/year
- Improved tire life
 - Properly maintained tires last 3.8% longer also reducing fossil fuel consumption

Social Impact

- Decrease rates of injuries and fatalities in the automotive fleet
- NHTSA reports 80 deaths annually and 10,500 injuries due to low tire pressure related issues

- Raises cultural awareness of tire related issues

- Seat belts are not enough, people have to wear them!

- Reduce dependence upon fossil fuels

- Enables ESP to work better

Key Technology Differences

- Historically V is not available
 - We have a very good velocity measurement with GPS
- Previous signal processing makes wrong assumptions
 - Developed new signal processing which works well in simulation and practice
- Less expensive than direct sensing methods
 - GPS World magazine advertises OEM GPS receivers for \$10
 - Adds value to existing GPS systems

Key Technology Differences

■ This system consistently performs an order of magnitude better than any other indirect method

- Yields more information than other indirect methods
- Detects tire behavior on an absolute scale (because of GPS)
- Other propose systems can only detect relative changes
- Tire radii subject to manufacturing variation on the order of the signal size (Daimler)
- Radius based schemes ruled to be unacceptable by NHTSA

Current Work

- Starting a company
 - Incorporating in California
 - Mission: Develop commercially viable tire monitor and license technology
 - IDEAs, SBIR funding to develop feasibility prototypes
 - Professor Gerdes has a degree in entrepreneurial management
 - The market: Congress mandates tire pressure monitors by 2006 (NHTSA)
- Developing industrial contacts at Daimler, Bosch, (GM)
 - Defining what it will take to make the product real

Current Work

- Patent filing
 - Broadening scope to include new vehicle sensor and actuator configurations
 - Working on 5th iteration of claims
 - Patent will be filed any day now
- Developing new stability control system to prevent vehicle rollovers
 - GPS and tire properties key enabling technologies